Input/Output Controller (IOC) Overview

Eric Norum

IOC Overview

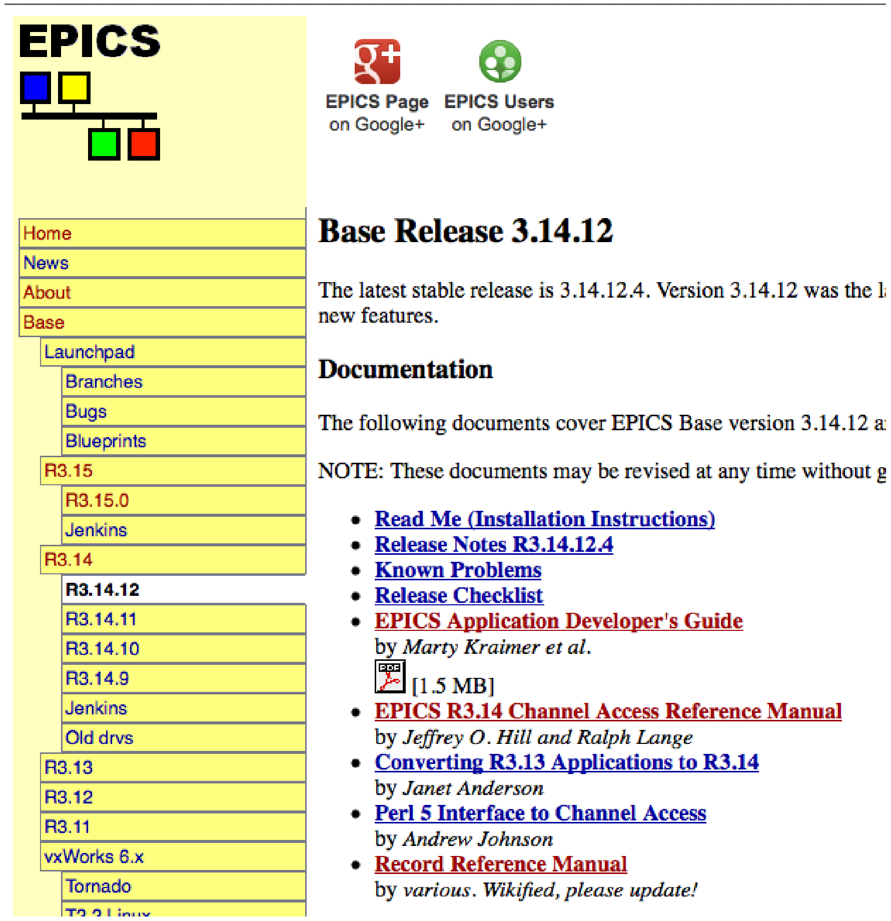
- What is an EPICS Input/Output Controller?
- How to create a new IOC application?
- How to build an IOC application?
- How to run an IOC application on various platforms?
- Console interaction with an IOC application (iocsh)

Reference

EPICS: Input/Output Controller

Application Developers Guide

Go to EPICS home page:
http://www.aps.anl.gov/epics/
then follow links:
BASE->R3.14->R3.14.12
Then click the "EPICS Application Developer's Guide"



Base Release 3.14.12

The latest stable release is 3.14.12.4. Version 3.14.12 was the l
new features.

Documentation

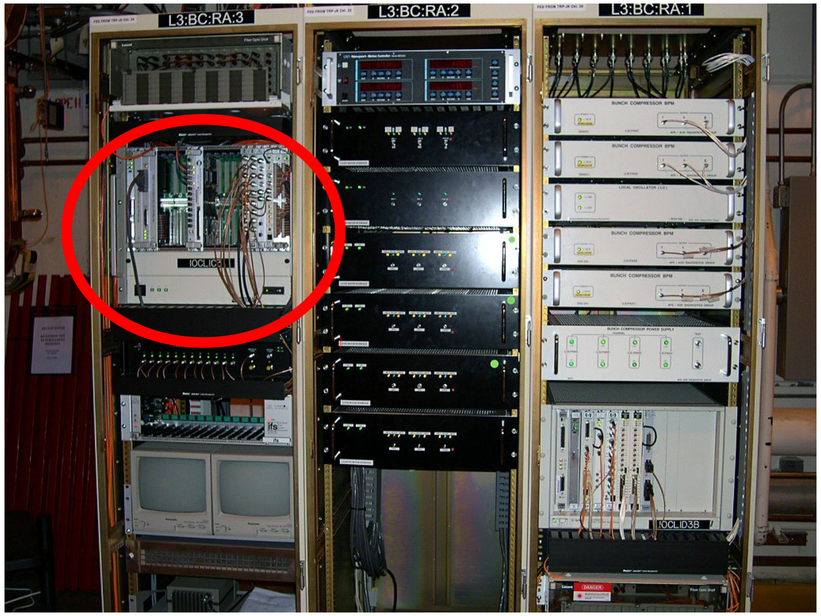
The following documents cover EPICS Base version 3.14.12 a

NOTE: These documents may be revised at any time without g

- Read Me (Installation Instructions)
- Release Notes R3.14.12.4
- Known Problems
- Release Checklist
- EPICS Application Developer's Guide
  by *Marty Kraimer et al.*
  [1.5 MB]
- EPICS R3.14 Channel Access Reference Manual
  by *Jeffrey O. Hill and Ralph Lange*
- Converting R3.13 Applications to R3.14
  by *Janet Anderson*
- Perl 5 Interface to Channel Access
  by *Andrew Johnson*
- Record Reference Manual
  by *various. Wikified, please update!*

What is an Input/Output Controller?

The answer used to be easy – “A single-board computer running the vxWorks real-time operating system and installed in a VME chassis”.



What is an Input/Output Controller?

An IOC can also be an embedded microcontroller, a rack-mount server, a laptop PC or Mac, a desktop PC or Mac, a standalone single-board computer or even an FPGA.

It may be running on Linux, Windows, Solaris, Darwin, RTEMS or vxWorks

What is an Input/Output Controller?

Some definitions:

- A computer running *iocCore,* a set of EPICS routines used to define process variables and implement real-time control algorithms

- *iocCore* uses database records to define process variables and their behavior

What does an Input/Output Controller do?

- As its name implies, an IOC often performs input/output operations to attached hardware devices.
- An IOC associates the values of EPICS process variables with the results of these input/output operations.
- An IOC can perform sequencing operations, closed-loop control and other computations.

‘Host-based’ and ‘Target’ IOCs

- ‘Host-based’ IOC
  - Runs in the same environment as which it was compiled
  - ‘Native’ software development tools (compilers, linkers)
  - Sometimes called a ‘Soft’ IOC
  - IOC is an program like any other on the machine
  - Possible to have many IOCs on a single machine
- ‘Target’ IOC
  - Runs in a different environment than where compiled
  - ‘Cross’ software development tools
  - vxWorks, RTEMS, Linux
  - IOC boots from some medium (network, flash memory)
  - IOC is the only program running on the machine

IOC Software Development Area

- IOC software is usually divided into different <top> areas
  - Each <top> provides a place to collect files and configuration data associated with one or more similar IOCs
  - Each <top> is managed separately
  - A <top> may use products from other <top> areas (EPICS base, for example can be thought of as just another <top>)

IOC Software Development Tools

- EPICS uses the GNU version of make
  - Almost every directory from the <top> on down contains a ‘Makefile’
  - Make recursively descends through the directory tree
    - Determines what needs to be [re]built
    - Invokes compilers and other tools as instructed in Makefile
  - GNU C/C++ compilers or vendor compilers can be used

IOC Application Development Examples

The following slides provide step-by-step examples of how to:

- Create, build, run the example IOC application on a 'host' machine (Linux, Solaris, Darwin, etc.)
- Create, build, run the example IOC application on a vxWorks 'target' machine

Each example begins with the use of ‘makeBaseApp.pl’

The ‘makeBaseApp.pl’ program

- Part of EPICS base distribution
- Populates a new, or adds files to an existing, <top> area
- Requires that your environment contain a valid EPICS_HOST_ARCH (EPICS base contains scripts which can set this as part of your login sequence)
  - linux-x86_64, darwin-x86, win32-x86
- Creates different directory structures based on a selection of different templates
- Commonly-used templates include
  - ioc - Generic IOC application skeleton
  - example - Example IOC application

Creating and initializing a new <top>

- Create a new directory and run makeBaseApp.pl from within that directory
  - mkdir lectureExample
  - cd lectureExample
  - /opt/epics/iocapps/R3.14.12/base/bin/linux-x86_64/makeBaseApp.pl -t example first

---

- Provide full path to makeBaseApp.pl script to ensure particular version of base:

  <base>***/bin/***<arch>***/makeBaseApp.pl***
- The template is specified with the '***–t***' argument
- The application name (firstApp) is specified with the '***first***' argument

<top> directory structure

- The makeBaseApp.pl creates the following directory structure in <top>:

configure/	**- Configuration files**
firstApp/	**- Files associated with the ‘firstApp’ application**
Db/	- Databases, templates, substitutions
src/	- Source code

- Every directory contains a ‘Makefile’

<top>/configure files

- Some may be modified as needed
  - CONFIG_SITE

    Specify make variables (e.g. to build for a particular target):

    CROSS_COMPILER_TARGET_ARCHS = vxWorks-68040
  - RELEASE

    Specify location of other <top> areas used by applications in this <top>area.
- Others are part of the (complex!) build system and should be left alone.

Create a host-based IOC boot directory

- Run makeBaseApp.pl from the <top> directory
- ‘***-t example***’ to specify template
- ‘***-i***’ to show that IOC boot directory is to be created
- ‘***-a*** <*arch*>’ to specify hardware on which IOC is to run
- name of IOC

➢ ***makeBaseApp.pl-t example -i -a linux-x86_64 first***

- If you omit the ‘-a <*arch*>’ you may be presented with a menu of options from which to pick

<top> directory structure

- The command from the previous page creates another directory in <top>:

iocBoot/	**- Directory containing per-IOC boot directories**
iocfirst/	- Boot directory for ‘iocfirst’ IOC

Build the application

- Run the GNU make program
  - ‘make’ on Darwin, Linux, Windows
  - ‘gnumake’ on Solaris

➢ ***`make`***

or

➢ ***`make -w`***

- Runs lots of commands

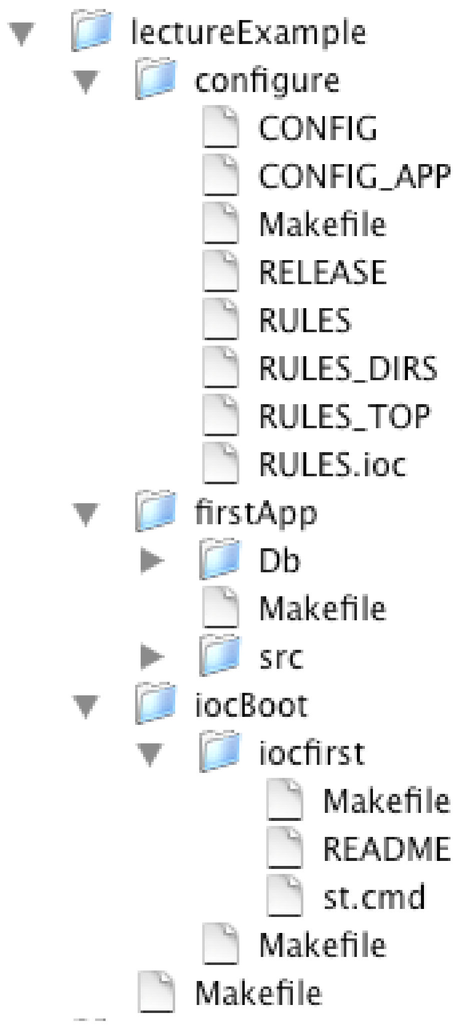
<top> directory structure after running ***`make`***

- These additional directories are now present in <top>

bin/	**- Directory containing per-architecture directories**
linux-x86_64/	**- Object files and executables for this architecture**
lib/	**- Directory containing per-architecture directories**
linux-x86_64/	**- Object libraries for this architecture**
dbd/	**- Database definition files**
db/	**- Database files (record instances, templates)**

- There may be other directories under bin/ and lib/, too**.**

<top> directory structure after running **`make`**



```
lectureExample
    configure
        CONFIG
        CONFIG_APP
        Makefile
        RELEASE
        RULES
        RULES_DIRS
        RULES_TOP
        RULES.ioc
    firstApp
        Db
        Makefile
        src
    iocBoot
        iocfirst
            Makefile
            README
            st.cmd
        Makefile
    Makefile
```

IOC startup

- IOCs read commands from a startup script
  - Typically ‘st.cmd’ in the <top>/iocBoot/<iocname>/ directory
- vxWorks IOCs read these scripts with the vxWorks shell
- Other IOCs read these scripts with the iocsh shell
- Command syntax can be similar but iocsh allows more familiar form too
- Script was created by ‘makeBaseApp.pl -i’ command
- For a ‘real’ IOC you’d likely add commands to configure hardware modules, start sequence programs, update log files, etc.

Example application startup script

```
#!../../bin/linux-x86_64/first

## You may have to change first to something else
## everywhere it appears in this file

< envPaths

cd ${TOP}

## Register all support components
dbLoadDatabase("dbd/first.dbd")
first_registerRecordDeviceDriver(pdbbase)

## Load record instances
dbLoadRecords("db/dbExample1.db","user=norumeHost")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=1,scan=1 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=2,scan=2 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=3,scan=5 second")
dbLoadRecords("db/dbSubExample.db","user=norumeHost")

## Set this to see messages from mySub
#var mySubDebug 1

cd ${TOP}/iocBoot/${IOC}
iocInit()

## Start any sequence programs
#seq sncExample,"user=norumeHost”
```

Example application startup script

```
#!../../bin/linux-x86_64/first
```

- This allows a host-based IOC application to be started by simply executing the st.cmd script
- If you’re running this on a different architecture the ‘linux-x86’ will be different
- If you gave a different IOC name to the ‘makeBaseApp.pl -i’ command the ‘first’ will be different
- Remaining lines beginning with a ‘#’ character are comments

Example application startup script

6 < envPaths

- The application reads commands from the ‘envPaths’ file created by ‘makeBaseApp -i’ and ‘make’
- The envPaths file contains commands to set up environment variables for the application:
  - Architecture
  - IOC name
  - <top> directory
  - <top> directory of each component named in configure/RELEASE
- These values can then be used by subsequent commands

```
epicsEnvSet(ARCH,"linux-x86")
epicsEnvSet(IOC,"iocfirst")
epicsEnvSet(TOP,"/home/NORUME/lectureExample")
“epicsEnvSet(EPICS_BASE,"/opt/epics/iocapps/R3.14.6/base")
```

Example application startup script

```
8  cd ${TOP}
```

- The working directory is set to the value of the ${TOP} environment variable (as set by the commands in ‘envPaths’)
- Allows use of relative path names in subsequent commands
- Should really be in quotes in case the ‘TOP’ value contains spaces

Example application startup script

```
11  dbLoadDatabase("dbd/first.dbd")
```

- Loads the database definition file for this application
- Describes record layout, menus, drivers

Example application startup script

```
12  first_registerRecordDeviceDriver(pdbbase)
```

- Registers the information read from the database definition files

Example application startup script

```
dbLoadRecords("db/dbExample1.db","user=norumeHost")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=1,scan=1 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=2,scan=2 second")
dbLoadRecords("db/dbExample2.db","user=norumeHost,no=3,scan=5 second")
dbLoadRecords("db/dbSubExample.db","user=norumeHost")
```

- Read the application database files
  - These define the records which this IOC will maintain
  - A given file can be read more than once (with different macro definitions)

Example application startup script

```
cd ${TOP}/iocBoot/${IOC}
```

- The working directory is set to the per-IOC startup directory
- Again, should be in quotes

Example application startup script

25 iocInit()

- Activates everything
- After reading the last line of the 'st.cmd' script the IOC continues reading commands from the console
  - Diagnostic commands
  - Configuration changes

Running a host-based IOC

- Change to IOC startup directory (the one containing the st.cmd script)
  - ➢ *cd iocBoot/iocfirst*
- Run the IOC executable with the startup script as the only argument
  - ➢ *../../bin/linux-x86_64/first st.cmd*
- The startup script commands will be displayed as they are read and executed
- When all the startup script commands are finished the iocsh will display an '*epics>* ' prompt and wait for commands to be typed.

```
iocInit()
######################################################################
###  EPICS IOC CORE built on Jun 23 2004
###  EPICS R3.14.6 $R3-14-6$ $2004/05/28 19:27:47$
######################################################################
Starting iocInit
## Start any sequence programs
#seq sncExample,"user=norumeHost"
iocInit: All initialization complete
epics>
```

Some useful iocsh commands

- **Display list of records maintained by this IOC**

```
epics> dbl
norumeHost:aiExample
norumeHost:aiExample1
norumeHost:aiExample2
norumeHost:aiExample3
norumeHost:calcExample
norumeHost:calcExample1
norumeHost:calcExample2
norumeHost:calcExample3
norumeHost:compressExample
norumeHost:subExample
norumeHost:xxxExample
```

- Caution – some IOCs have a lot of records

Some useful iocsh commands

- **Display a record**

```
epics> dbpr norumeHost:aiExample
ASG:                DESC: Analog input  DISA: 0             DISP: 0
DISV: 1             NAME: norumeHost:aiExample              RVAL: 0
SEVR: MAJOR         STAT: HIHI          SVAL: 0             TPRO: 0
VAL: 9
epics> dbpr norumeHost:aiExample
ASG:                DESC: Analog input  DISA: 0             DISP: 0
DISV: 1             NAME: norumeHost:aiExample              RVAL: 0
SEVR: MINOR         STAT: LOW           SVAL: 0             TPRO: 0
VAL: 4
```

- ***`dbpr <recordname> 1`*** prints more fields
- ***`dbpr <recordname> 2`*** prints even more fields, and so on

Some useful iocsh commands

- **Show list of attached clients**

```
epics> casr
Channel Access Server V4.11
No clients connected.
```

- ***`casr 1`*** prints more information
- ***`casr 2`*** prints even more information

Some useful iocsh commands

- **Do a ‘put’ to a field**

```
epics> dbpf norumeHost:calcExample.SCAN "2 second"
DBR_STRING:          2 second
```

- Arguments with spaces must be enclosed in quotes

Some useful iocsh commands

- **The ‘help’ command, with no arguments, displays a list of all iocsh commands**
  - 100 or so, plus commands for additional drivers
- **With arguments it displays usage information for each command listed**
- **Wildcard characters (‘?’, ‘*’) can be used**

```
epics> help dbl dbpr dbpf
dbl 'record type' fields
dbpr 'record name' 'interest level'
dbpf 'record name' value
```

Terminating a host-based IOC

- **Type ‘*`exit`*’ to the iocsh prompt**
- **Type your ‘interrupt’ character (usually control-C)**
- **Kill the process from another terminal/window**

Create a vxWorks IOC boot directory

- Almost the same as for a host-based IOC
  - just the ***<arch>*** changes
- Run makeBaseApp.pl from the <top> directory
- '***-t example***' to specify template
- '***-i***' to show that IOC boot directory is to be created
- '***-a*** *<arch>*' to specify hardware on which IOC is to run
- name of IOC

➢ ***makeBaseApp.pl -t example -i -a vxWorks-68040 first***

vxWorks IOC startup script changes

- The startup script created by '***`makeBaseApp.pl –i`***' for a vxWorks IOC is slightly different than one created for a host-based IOC
- A vxWorks IOC uses the vxWorks shell to read the script
  - a host-based IOC uses the iocsh shell
- A vxWorks IOC incrementally loads the application binary into the vxWorks system
  - A host-based IOC runs as a single executable image

vxWorks IOC startup script changes

- The first few lines of the example st.cmd script for a vxWorks target are:

```
## Example vxWorks startup file

## The following is needed if your board support package doesn't at boot time
## automatically cd to the directory containing its startup script
#cd "/home/phoebus/NORUME/lectureExample/iocBoot/iocfirst”

< cdCommands
#< ../nfsCommands

cd topbin
## You may have to change first to something else
## everywhere it appears in this file

ld < first.munch
```

vxWorks IOC startup script changes

- There is no ‘#!’ line at the beginning of the script
- vxWorks IOCs can’t be started by simply executing the startup script

vxWorks IOC startup script changes

- The startup script reads more commands from cdCommands rather than from envPaths
  - Assigns values to vxWorks shell variables rather than to iocsh environment variables
- Subsequent ‘cd’ commands look like

```
cd top
```

rather than

```
cd ${TOP}
```

vxWorks IOC startup script changes

- The startup script contains command to load the binary files making up the IOC application

  ```
  ld < first.munch
  ```

  - Binary fragments have names ending in ‘.munch’

Running a vxWorks IOC

- **Set up the vxWorks boot parameters**

```
Press any key to stop auto-boot...
 6
[VxWorks Boot]: c
'.' = clear field;  '-' = go to previous field;  ^D = quit
boot device           : ei
processor number      : 0
host name             : phoebus
file name             : /usr/local/vxWorks/T202/mv167-asd7_nodns
inet on ethernet (e)  : 192.168.8.91:fffffc00
inet on backplane (b):
host inet (h)         : 192.168.8.167
gateway inet (g)      :
user (u)              : someuser
ftp password (pw) (blank = use rsh): somepassword
flags (f)             : 0x0
target name (tn)      : iocnorum
startup script (s)    : /usr/local/epics/iocBoot/iocfirst/st.cmd
other (o)             :
```

Running a vxWorks IOC

`host name :`	Name of your FTP server
`file name :`	Path to the vxWorks image on the FTP server
`inet on ethernet (e) :`	IOC IP address/netmask
`inet on backplane (b):`	
`host inet (h) :`	FTP server IP address
`gateway inet (g) :`	
`user (u) :`	User name to log into FTP server
`ftp password (pw) (blank = use rsh):`	Password to log into FTP server
`flags (f) :`	Special BSP flags
`target name (tn) :`	IOC name
`startup script (s) :`	Path to IOC startup script on FTP server
`other (o) :`	

- **Once these parameters have been set a reboot will start the IOC**

vxWorks shell

- The vxWorks shell requires that commands be entered in a slightly different form
  - String arguments must be enclosed in quotes
  - Arguments must be separated by commas
  - There is no ‘help’ command
  - Many vxWorks-specific commands are available
- For example, the ‘dbpf’ command shown previously could be entered as:

```
dbpf “norumeHost:calcExample.SCAN”,”2 second”
```

- or as:

```
dbpf(“norumeHost:calcExample.SCAN”,”2 second”)
```

Review

- IOC applications can be host-based or target-based
- The makeBaseApp.pl script is used to create IOC application modules and IOC startup directories
- <top>/configure/RELEASE contents specify location of other <top> areas used by this <top> area
- <top>/iocBoot/<iocname>/st.cmd is the startup script for IOC applications
- The EPICS build system requires the use of GNU make
- vxWorks IOCs use the vxWorks shell, non-vxWorks IOCs use iocsh
- The EPICS Application Developer’s Guide contains a wealth of information